Fabrication of Normal Incidence Mirrors by a Nickel Replication Process

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Space telescopes that are larger, lighter, and less costly than ever before are a step closer to reality due to a novel mirror fabrication technique under development at MSFC. Mirrors that are over 10 times lighter than current space technology will enable larger, lighter optical systems with unprecedented performance. Similarly, manufacturing costs are reduced since the critical and time-consuming task of grinding and polishing glass is eliminated.

Conventional mirror manufacturing techniques applied to large normal incidence mirrors are extremely expensive and time consuming as evidenced by the extreme cost of the Hubble Space Telescope primary mirror. Also, a conventional glass mirror must be relatively massive so that it can possess enough rigidity to be finished, ground and polished to its final figure. A conventional glass mirror must also survive the launch environment, making the mirror even heavier. The brittle nature of glass, combined with low strength and high-manufacturing costs, severely limits our ability to economically launch future astronomy missions the size of Hubble or larger. In short, higher performance in space optical systems cannot be realized until a lighter, more economical replacement to conventional glass mirror technology is developed.

Fabrication of normal incidence mirrors by nickel replication is an alternative to conventional mirror technology which exploits manufacturing economy in a low-weight system. Figure 109 depicts the process. As shown, nickel is electroplated onto a highly polished mandrel (typically aluminum) to a thickness of around 1 mm.

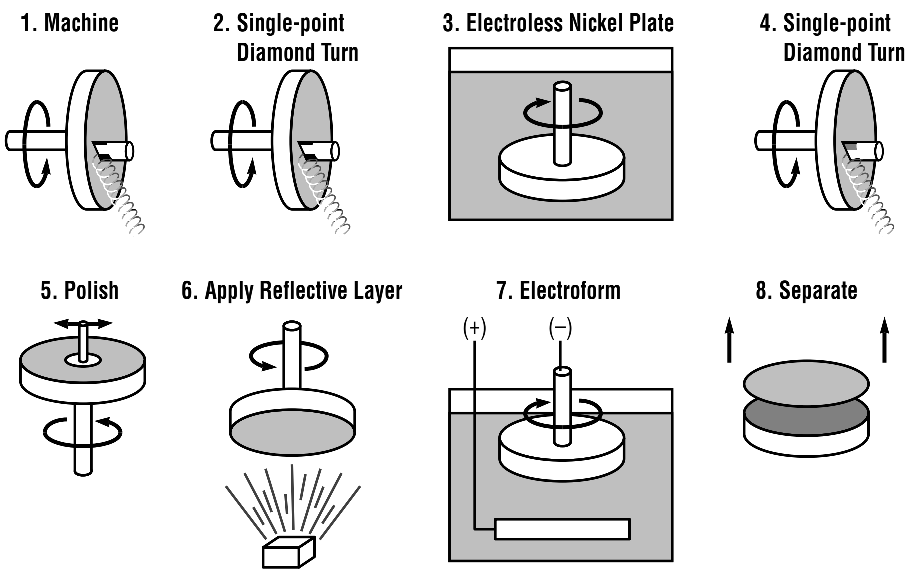

FIGURE 109.—Replication applied to normal incidence optics. (1) Machine; (2) Single-point diamond turn; (3) Electroless nickel plate; (4) single-point diamond turn; (5) Polish; (6) Apply reflective layer; (7) Electroform; (8) Separate.

Once the desired thickness is achieved, the nickel “shell” is released from its mandrel leaving an optical quality surface. The nickel shell (mirror) can then be laminated onto a lightweight composite structure thus producing a mirror 10 times lighter than that of conventional manufacture. Since the mandrel can be reused, multiple mirrors can be produced in a short time, thus allowing spare units, or multiple segments, of a larger mirror to be produced.

As mirrors are fabricated thinner, the effects of mounting and holding become increasingly sensitive to the optical surface. Fastening, bonding, and joining of typical optical substrates to adjacent structures are particularly problematic. These effects are known as “print-thru” or “quilting.” In nickel replication techniques, these effects can be mitigated since the nickel electroplating process lends itself to the ability to plate to the optic an intricate array of flexures, or mounting provisions. The plating technique also lends itself to the ability to produce odd shaped mirrors which would be particularly difficult by conventional methods. This facilitates the production large segmented mirrors comprised of “petals” which would unfurl and lock into position upon insertion into orbit.

The fact that nickel can be fabricated in very thin sections, along with its characteristics of high strength, nonbrittle behavior, make it an excellent candidate for adaptive schemes as well. Adaptive schemes would be used to correct residual errors in the telescope due to inherent deployment errors, gravity release, and the like. Here, the thin nickel “shell,” or membrane is actually “shaped” by an array of electromechanical or electrostrictive actuators. The application of adaptive schemes allows for residual correction of the optic, and/or compensation of errors and disturbances elsewhere in the optical path of the telescope. An example of this would be the correction of atmospheric disturbances in ground-based telescopes.

Current research is focused on the production of subscale prototype mirrors to be used in structural, environmental, and optical testing. The key parameters involve control of the plating bath so a mirror is produced having zero residual stress. Zero residual stress in the plating process produces a high-quality optic which truly replicates the optical prescription of the mandrel. As of this report, several one-quarter-meter-diameter mirrors have been produced with remarkable results. A larger half-meter-diameter mirror is scheduled for 1997. Upon successful completion of the half-meter program, it is hoped that a flight experiment can be scheduled to test the mirrors in an actual space environment at cryogenic temperatures.

This research will allow NASA to build the next generation of space telescopes with substantially lower cost and higher performance. The production of light-weight, low-cost, high-performance optics will usher in a new era for astronomy, and spawn countless benefits to the commercial and military sectors by allowing large, high-performance optical systems to be transported to places that are today impossible. The mass production of large, super-precision, intricate parts is now economically feasible; electroforming can produce parts in virtually any shape or form. Potential applications are limitless.

Sponsor: Office of Space Science

University/Industry Involvement: UAH/CAO, Darell Engelhaupt

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